Water Quality Modeling of the Lower Columbia and Snake River Systems

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Objectives

- Present a brief comparison of key characteristics of 3 recent water quality models applied to the Columbia and Snake River systems
- Consumer Warning: may reflect my incomplete knowledge about the other modeling work (if in doubt - refer to original reports and authors)

Models

- Pacific Northwest National Laboratory (PNNL) - Richmond and Perkins
  - MASS1 : 1D, unsteady hydrodynamics and water quality (temperature and dissolved gas)
  - MASS2 : 2D depth-averaged hydrodynamics and water quality (temperature and dissolved gas)
  - active development and maintenance of models
- US EPA, Region 10 (EPA) - Yearsley
  - 1D, steady hydrodynamics, unsteady water quality (temperature)
  - active development and maintenance of model
- Normandeau Associates
  - WQRRS : 1D, unsteady hydrodynamics and water quality, biology
  - “off the shelf application”, WQRRS does not appear to be actively maintained ?

General Snake River Application Features

- PNNL MASS1
  - applied to current and unimpounded conditions
- PNNL MASS2
  - applied to current and unimpounded conditions
- EPA
  - applied to current and unimpounded conditions
- WQRRS
  - applied only to unimpounded conditions

Geographic Domain

- PNNL MASS1
  - Columbia river mile 25 upstream to Keenleyside, Dworshak, Hells Canyon
  - Snake application is a subset (SRM 0 - 168)
- PNNL MASS2
  - Portland upstream to Kennewick, Lewiston, Snake River Mile 168
- EPA
  - Bonneville upstream to Grand Coulee and Lewiston (SRM 139)
- WQRRS
  - Snake River Mile 0 to 146
- (focus on the 1D models from here on)

Time Periods for Snake River Applications

- PNNL MASS1
  - 1996, 1997 : verification
  - 1960 -1995 : application (with/without dams)
- EPA
  - 1990-1995 : calibration(?)
  - 1975-1995 : application (with/without dams)
- WQRRS
  - 1956-1958 : “calibration” - Central Ferry??
  - 1994, 1995, 1997 : application (without dams)

Hydrodynamic and Transport Numerical Methods

- PNNL MASS1
  - Hydrodynamics
    - » full dynamic method (St. Venant) - standard implicit Preissman scheme
  - Transport
    - » explicit TVD for advection - minimal numerical diffusion
    - » split operator for diffusion and source terms (e.g., surface heat flux)
    - » sub time for transport (hydrodynamics not limited to transport time step)
- EPA
  - Hydrodynamics
    - » Standard steady flow methods and level pool assumption
  - Transport
    - » Lagrangian scheme - minimal numerical diffusion
- WQRRS
  - Hydrodynamics
    - » modified puls hydrologic (mass balance) method
    - » St. Venant finite-element method not used because of stability problems
  - Transport
    - » Upwind differencing for advection - causes numerical diffusion

Surface Heat Exchange Methods

- PNNL MASS1
  - surface heat flux
- EPA
  - surface heat flux
- WQRRS
  - surface heat flux
- All methods use very similar parameterizations
- River bathymetry is important because surface heat flux term is inversely proportional to water depth

Bathymetry and Spatial Resolution

- PNNL MASS1 and MASS2
  - latest COE surveys, NOAA charts, USGS DEMS, 1934 COE survey for unimpounded conditions
  - automated cross-section generation using Arc/Info GIS system
  - 0.5 mile spatial resolution (finer in some areas)
- EPA
  - NOAA charts, HEC-2 input data, Other sources
  - variable, 1 - 10 mile resolution
- WQRRS
  - 1934 COE survey for unimpounded conditions
  - variable, limited by model memory constraints, about 1 mile

Hydrology and Meteorology

- PNNL MASS1
  - hourly flows, water temperature, met data for 1996, 1997
  - daily flows and water temperatures 1960-1995
  - hourly met data for 1960-1995 (Lewiston)
- EPA
  - daily average flows?
  - hourly met data? (Lewiston)
- WQRRS
  - daily average flows
  - daily met data with computed hourly radiation (Lewiston and Pasco)

Application Results

- PNNL MASS1
  - frequency analysis of long-term simulations for current and unimpounded conditions
  - dams have reduced temperature variations
  - August 50% exceedance temperature at Ice Harbor Dam Location (SRM 9.5)
    - » With Dams : 19.5 deg. C
    - » Without Dams : 20.6 deg. C
  - dams shift temperatures cooler in Spring and warmer in Fall compared to unimpounded conditions
  - considering all the uncertainties, the absolute temperature difference may not be significant
  - additional analysis required to assess uncertainty

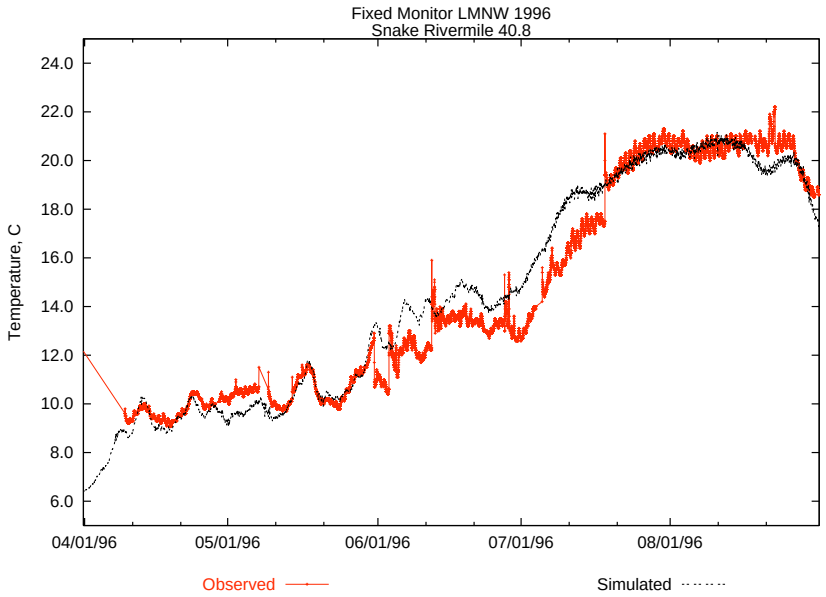
Application Results, cont.

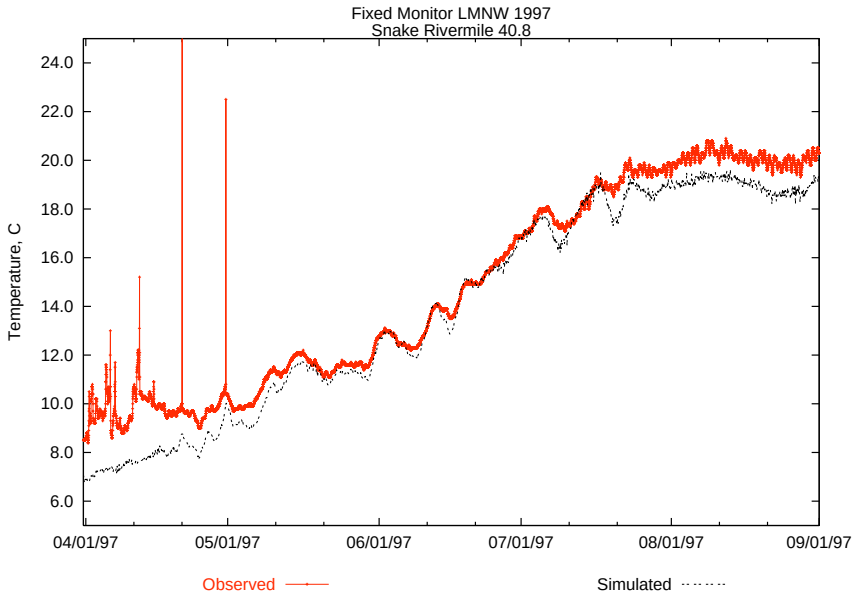
- EPA
  - frequency analysis of long-term simulations for current and unimpounded conditions
  - at the Ice Harbor Dam location the magnitude of exceeding 20 deg C is
    - » with dams : 1.8 deg. C
    - » without dams : 1.2 deg. C
  - at the Ice Harbor Dam location the frequency of exceeding 20 deg C is
    - » with dams : about 0.18 (figure 30)
    - » without dams : about 0.12 (figure 31)

Application Results, cont.

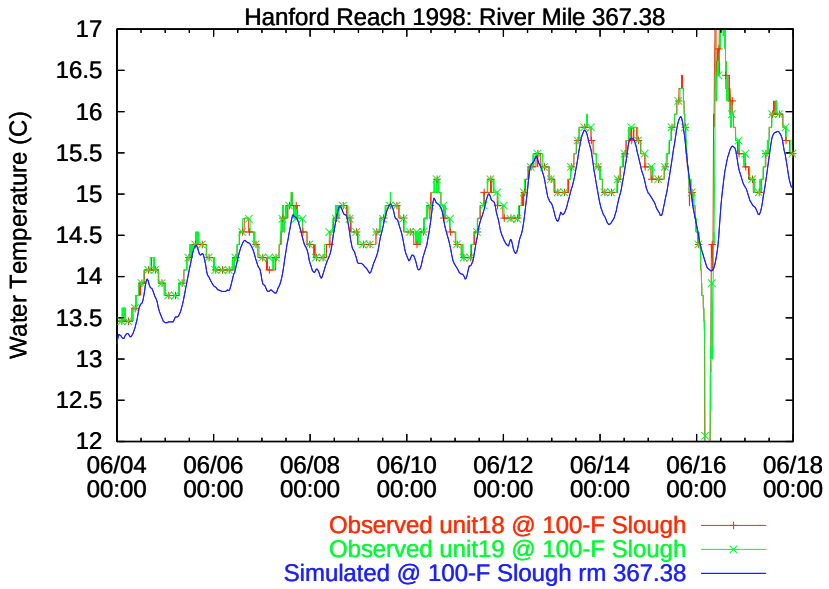
- WQRRS
  - general comparison of unimpounded simulation for 1994, 1995, 1997 to measured data for current conditions at specific locations for same years
  - higher water temperatures without dams

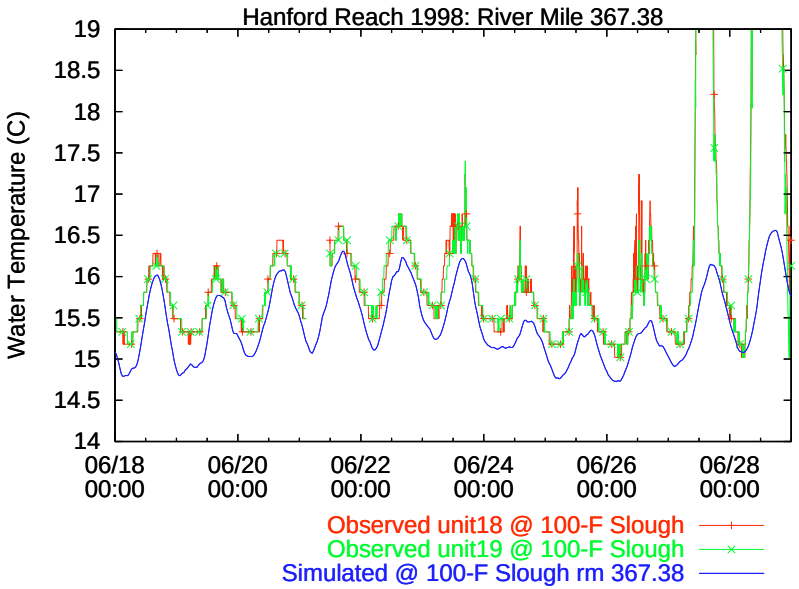
MASS1 - Lower Monumental Fixed Monitor Comparison



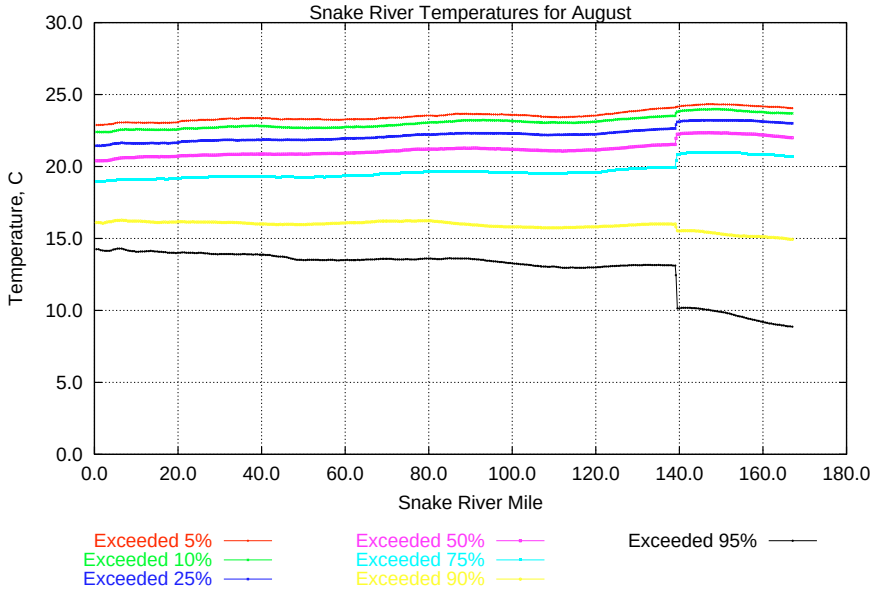


MASS1 - Verification for Hanford Reach 100-F Slough (RM 367)

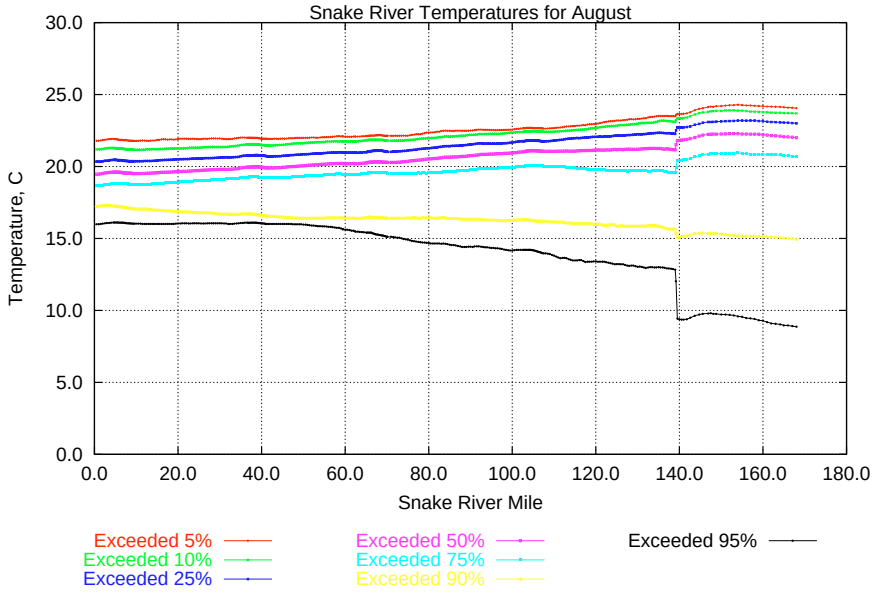




MASS1 - Snake River Ave. August Profile

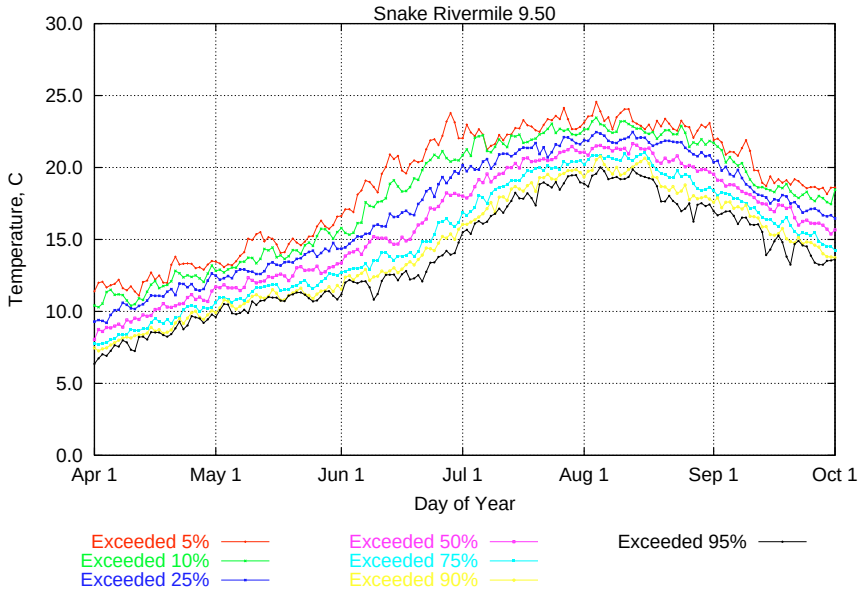


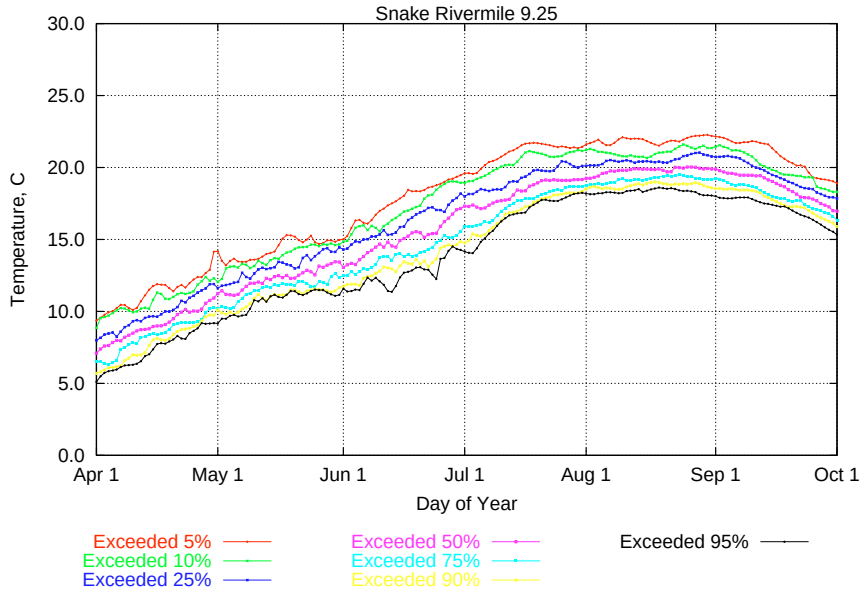
Unimpounded (without dams)



Current (with dams)

MASS1 - Temperature Variation at Ice Harbor Dam Location





Unimpounded (without dams)

Current (with dams)